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Explorative learning (Model of HOTL-DI Type B) about the pottery production

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Abstract
This article describes a summary of the results of explorative learning using the model: Higher Order Thinking Learning in Democratic Interaction (HOTL-DI) type B, regarding the pottery production. There are three stages of exploration activities. The first stage is the exploration of objects, concepts and physical processes by the research team as a reference to facilitate students in learning activities. The second stage is exploration by 5th semester students (trial group). The third stage is exploration by 3rd semester students (target group). The results showed that students experienced difficulties at each step at the beginning of the exploration process. This difficulty is caused by a lack of experience in exploring physics concepts and processes in the environment utilizing local wisdom. The ability to explore utilizing local wisdom continues to increase at each meeting.

Keywords: explorative learning, higher order thinking, pottery production

1. Introduction

Physics is the study of natural phenomena and its purpose is to explain how these natural phenomena occur. Students have difficulty learning physics in terms of application where students find it difficult to visualize concepts in their imagination; they cannot solve the problem in the subject; and finally, they cannot put their knowledge into practice [1]. Learning physics is actually lacking if it only learns from what is already in the textbook and does not go directly to the real object, namely nature. Students can learn the logic of the laws of physics that apply in nature [2]. Activities in nature make the learning process more real, not just taking knowledge directly from the teacher. The activity of integrating the context in nature with the concepts obtained in the classroom can be done through explorative learning.

Explorative learning is a learning that aims to explore ideas from students so that it can lead students to understanding a concept and solving problems [3]. In this case, students become active explorers and the teacher only acts as a guide and facilitator of the exploration. Exploring activities in understanding learning material makes learning more meaningful [4]. Explorative learning provides opportunities for students to construct their own knowledge based on the ideas and facts learned. Explorative learning provides a learning atmosphere that encourages students to build skills in understanding concepts and processes that occur in the context in their environment so as to develop students' critical thinking skills.

In relation to explorative learning in nature, physics learning resources can also be found in community life which is reflected in local wisdom. Local wisdom means harmonious relationship between man, nature and the built environment in an area that is also influenced by its culture [5]. Local wisdom has physical values that have not been fully explored. One form of improving the quality of physics learning is by utilizing existing local wisdom. This makes students actively involved in seeing and directly experiencing natural phenomena that occur which have only been studied in textbooks. Pottery is a local wisdom in Minahasa. Each stage of pottery production can be explained by a physical concept and process.

The exploration process formulated by Medellu and Silangen (2019) [6] in Explorative Learning (Model of HOTL-DI Type B) consists of 4 steps: (1) Identification of facts / phenomena, (2) analysis of descriptions of local wisdom and facts / phenomena, (3) exploration of concepts and scientific processes / physics, (4) formulation of concept networks / formulations. There are three main stages of explorative learning (Model of HOTL-DI Type B): exploration by the research team, explorative learning to the trial group, and explorative learning to the target group. The model of this research is applied to Physics Department students. This research is a collaborative study that assesses the individual higher-order thinking learning process and the democratic process in group discussions (HOTL-DI). Specifically, this research assessing the higher order thinking learning process. This study aims to: (a) explore the concepts and physical processes about the pottery production, (b) determine the learning process of higher order thinking in exploring the concepts and physical processes about the pottery production.

2. Conceptual Framework

Higher Order Thinking Learning (HOTL)

Higher order thinking is a higher level of thought than memorizing facts and explaining them again [7]. Higher order thinking is a cognitive process that includes the ability to make decisions (judgment), generalize ideas, explore consequences, review opinions, monitor progress, and so on [8, 9]. Brookhart (2010) in Collins (2014) [10] classifies HOTL into three parts, namely HOTL as transfer, HOTL as critical thinking and HOTL as a problem-solving process. The problem-solving process is an activity that involves various actions in the mind including accessing and using knowledge from experience. Therefore, HOTL is a process of thinking skills broadly and deeply, not only memorizing and receiving information just like that but involving critical and creative thinking skills in solving problems. The era that continues to develop requires each individual to be able to think at a higher level. By getting used to learning to think at a high level, students are not only able to memorize and remember the learning material received but are able to solve problems critically and creatively with objects encountered in nature based on learning materials that have been obtained in formal education.

Explorative Learning Model (HOTL-DI Type B)

The explorative learning used by the research team was formulated by Medellu and Silangen in 2019[6], namely the HOTL-DI Explorative Learning Model type B, using the Exploratory Format-3 (HOTL Process) which directs higher-order thinking learning activities.

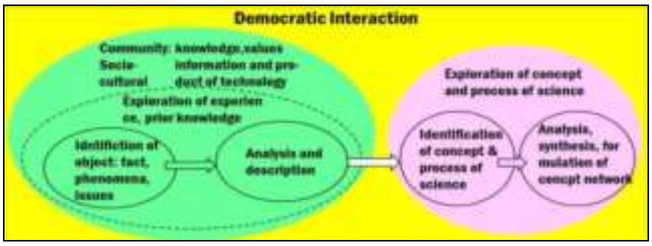


Fig 1: HOTL-DI Model Type B

This explorative learning model is used for learning objects related to socio-cultural and social issues. This model emphasizes the importance of acquiring information, knowledge and values in society. The assumption of this model is that knowledge and values in society form or frame individual experiences in understanding and analyzing facts and phenomena in the environment. Modification of model B from A is the framing of knowledge and values in society towards the construction of empirical experiences, impressions and individual responses. Format-3 is an exploration format that includes exploration of experiences, impressions and perceptions (blue column) and exploration of scientific concepts and processes (pink column).

Table 1: Fomat-3 Exploration (HOTL Process)

(1) Phenomenon Identification	(2) Description Analysis		(3) Exploration of Physical Concepts and Processes	(4) Synthesis - Analysis - Formulations
	(a) Local Wisdom	(b) Description of Fact Analysis		

Explanation of column contents

1. The column of phenomenon identification. This column is filled with the main elements of the phenomenon on which to base learning.
2. The column of description analysis. This column is filled with the analyze descriptions of phenomena from (a) local wisdom and (b) facts in order to obtain a clear picture of the phenomena that occur.
3. The column of exploration of physical concepts and processes. This column is filled with the exploration of concepts and physical processes of phenomena related to variables, the relationship between variables and finding references to gain reinforcement from the results of the phenomenon analysis.
4. The column of synthesis - analysis - formulations. This column is filled with synthesis analysis and formulation of context relationships (object-related phenomena) with physical concepts and processes.

3. Methods

This study is an explorative research using the model of Explorative Learning HOTL-DI type B by Medellu and Silangen in 2019, using a mixed-method design with qualitative and quantitative data. This study explores the production of pottery and explores to find out the thinking process of research subjects in higher-order thinking processes in the exploration of concepts and physical processes. The research subjects were students of Physics Department who are prospective teachers. This study was conducted in three main stages:

a) First Stage: Exploration by Researchers

This stage aims to (1) provide experiences to researchers in the exploration stages of objects, concepts, and processes (2) produce an exploration matrix reference that is used by researchers to facilitate exploratory learning activities for trial / mentor and target groups. In the first stage the research team identified and formulated choices of learning activities used by the trial and target groups. In this exploration process the research team was facilitated by lecturers.

b) Exploration by Trial Group (5th Semester Students)

This stage aims to (1) provide the experience of doing the exploration stage individually (2) produce an exploration matrix (3) recruit mentors for the next stage. The research team provided an exploration format for the trial group to fill in. The research team acts as a mentor who directs the trial group in the exploration stage. The research team reviewed the format filled in by the trial group as revision material for the next matrix reference. The completed format results are used as an assessment reference for the target group.
group.

c) Third stage: Exploration by Target Group (3rd Semester Students)

This stage aims to (1) provide the experience of doing the exploration stage individually (2) produce an exploration matrix. The research team provided an exploration format to be filled in by the target group. This last stage was facilitated by the research team together with the mentor who directed the target group to the exploration stage.

The research data were collected by giving the research subjects an Exploration Format-3 (HOTL Process) to be filled in according to their higher-order thinking skills in exploring the concepts and physical processes about pottery production. During the filling process, the format was not limited to the reference matrix designed by the research team, allowing the emergence of new concepts and processes outside the design of the research team matrix. The filled format is then assessed using an assessment rubric that has been prepared based on existing material indicators. Quantitative analysis in the form of the results of filling in Format-3 of the research subject, answer variations, consistency answer, and misconceptions answer. Qualitative analysis is related to the process of achieving scores and the achievement of exploration activities as well as the development of exploration skills from the initial meeting to the next meeting.

4. Results

The application of the HOTL-DI type B exploration learning model by Medellu and Silangen in 2019 to explore the higher-order thinking skills of physics students in exploring the concepts and physical processes about pottery production resulting in various answers. Most of the phenomena identification part is answered by describing the phenomenon of each step. The fact analysis description section often contains elements of local wisdom and is not explored scientifically. The exploration of concepts and physical processes as well as synthesis - analysis - formulation is still lacking. The results of exploration give rise to new answers, some of which are consistent but some of them deviate from the formulation of exploration results. The misconception answers that appear are controlled by reflective questions. New answers are added to the exploration matrix as revisions.

4.1 The Design of Exploration Activities by the Research Team

The results of the exploration carried out by the research team under the guidance of the lecturer resulted in the design of the material used as a reference for exploration learning activities. The material design consists of 5 steps based on the pottery production process, namely material processing, formation, drying, combustion and completion. The material designed is flexible. This is a supporting factor for the research team in exploration activities because exploration can be carried out openly and is not limited to certain materials.

Table 2: Exploration Matrix of Step 1

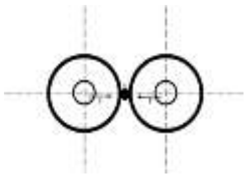
Phenomenon Identification	Description Analysis		Exploration of Physical Concepts and Processes	Synthesis - Analysis - Formulations
	Local Wisdom	Description of Fact Analysis		
Material Processing  *Milling machine*  *The inside of the milling machine*	Clay is taken and ground to smooth the clay.	Milling is the process of mechanically crushing the material to reduce the size of the solid so that the material becomes smooth.	▪ The fine material makes the constituent particles homogeneous, the heat distribution is evenly distributed ▪ Cross-sectional area of milling machine (A) ▪ External force (F)  ▪ The compressive stress of the clay (σ) ▪ The force needed to grind the clay (F)	▪ Cross-sectional area of milling machine (A) $A = l \; x \; w$ ▪ The compressive stress of the clay (σ) $\sigma = \frac{F}{A}$ ▪ The force needed to grind the clay (F) $F = \sigma . A . g$ where : g = Earth's gravitational acceleration (m/s^2)

Table 3: Exploration Matrix of Step 2

Phenomenon Identification	Description Analysis		Exploration of Physical Concepts and Processes	Synthesis - Analysis - Formulations
	Local Wisdom	Description of Fact Analysis		
Formation *Rotary tool*	The pottery body is formed using a rotary technique with the direction of rotation adjusting to the comfort of the craftsman.	Forming is the process of converting clay using a rotary tool into the desired shape.	▪ The radius of the rotary tool (r) ▪ The circle area of the rotary tool (L) ▪ Circumference of rotary tool (K) ▪ The angle produced by the	▪ The circle area of the rotary tool (L) ▪ $L = \pi r^2$ ▪ Circumference of rotary tool (K) ▪ $K = 2\pi r$

			rotary tool (θ) ▪ Travel time rotation (t) ▪ The angular velocity of rotary tool (ω) ▪ Period of rotary tool (T) ▪ Centripetal acceleration (a_s) ▪ Moment of inertia of rotary tool (I): moment of inertia in a solid cylinder of radius R, the location of the axis through the center  ▪ Rotational kinetic energy (KE_{rot}) ▪ The force that the hand exerts on the body of the potter (F) ▪ Normal force (N) ▪ Static coefficient of friction (μ_s) ▪ Kinetic coefficient of friction (μ_k) ▪ Static friction (f_s) ▪ Kinetic friction (f_k)	▪ The angular velocity of rotary tool (ω) $\omega = \frac{\theta}{t}$ ▪ Period of rotary tool (T) $T = \frac{2\pi}{\omega}$ ▪ Centripetal acceleration (a_s) $a_s = \omega^2 r$ ▪ Moment of inertia (I) $I = \frac{1}{2} M R^2$ ▪ Rotational kinetic energy $KE_{rot} = \frac{1}{2} I \omega^2$ ▪ Static friction (f_s) $f_s = \mu_s . N$ ▪ Kinetic friction (f_k) $f_k = \mu_k . N$

Table 4: Exploration Matrix of Step 3

Phenomenon Identification	Description Analysis		Exploration of Physical Concepts and Processes	Synthesis - Analysis - Formulations
	Local Wisdom	Description of Fact Analysis		
Drying  *The pottery is dried by aerating*	• The pottery that has been formed is dried first, not directly under the sun so that the pottery does not crack. • After drying, the pottery shrinks because the water content in the pottery decreases.	• Drying is the process of reducing the moisture content so that the pottery is denser so that it is not prone to cracks and breaks when burning. • The decrease in water content causes physical changes in materials / objects, the pottery loses some of the water it contains, causing shrinkage.	• Sudden evaporation causes the bond particles to break so that the pottery cracks and breaks. • Room temperature (T) • Atmospheric air pressure • High temperature, low humidity • High temperature, low air pressure • Strong wind speed causes faster drying time	• Room temperatre T = 27°C • Atmospheric air pressure 760 Hg = 1 atm • Ideal wind speed 19-35 km/h

Table 5: Exploration Matrix of Step 4

Phenomenon Identification	Description Analysis		Exploration of Physical Concepts and Processes	Synthesis - Analysis - Formulations
	Local Wisdom	Description of Fact Analysis		
Combustion *The furnace*	▪ Burning pottery using a furnace and setting the temperature from low to high because if it goes directly to a high temperature, the earthenware will crack. ▪ The tool for measuring the temperature during	▪ Combustion is a process carried out to change the mass of clay into solid, strong, and hard. The temperature is raised slowly so that the potter does not crack. ▪ Pyrometer is used to measure very high temperatures, because if you use an regular thermometer it will melt. In the Pyrometer,	▪ The sudden burning causes the ties to break so the pottery cracks and breaks ▪ The homogeneous constituent particles causes evenly distributed	• Celcius temperature scale R = (4/5) C F = (9/5) C + 32 K = C + 273 • Reamur temperature

	combustion is a Pyrometer which is placed close to the furnace. The combustion temperature is 600-650˚C.	temperature is determined by measuring the intensity of thermal radiation emitted by a very hot object.	heat ▪ Combustion temperature (T) • Thermal radiation • The greater the temperature, the greater the intensity of thermal radiation emitted • Celcius, Reamur, Fahrenheit, and Kelvin temperature scale	scale C = (5/4) R F = (9/4) R + 32 K = C + 273 or K = (5/4) R + 273 • Fahrenheit temperature scale C = 5/9 (F-32) R = 4/9 (F-32) K = 5/9 (F-32) + 273 • Kelvin temperature scale C = K – 273 R = 4/5 (K – 273) F = 9/5 (K-273) + 32

Table 6: Exploration Matrix of Step 5

Phenomenon Identification	Description Analysis		Exploration of Physical Concepts and Processes	Synthesis - Analysis - Formulations
	Local Wisdom	Description of Fact Analysis		
Completion  *Painted pottery*	▪ The potter is sanded to smooth the surface. ▪ Pottery is painted to make it look good to sell. The pottery is painted and then dried for 3-4 days.	▪ Sandpaper is used to make the surface of objects smoother by rubbing the rough surface of the sandpaper on the object. ▪ Paint is a liquid that is used to coat the surface of an object to beautify, strengthen and protect the object. After being applied to a surface and drying, the paint will form a thin layer that adheres firmly to the surface.	▪ The force applied by the sandpaper to the pottery (F) ▪ Normal force (N) ▪ Static coefficient of friction (μ_s) ▪ Kinetic coefficient of friction (μ_k) ▪ Static friction (f_s) ▪ Kinetic friction (f_k) ▪ Room temperature (T) ▪ Atmospheric air pressure ▪ High temperature, low humidity ▪ High temperature, low air pressure ▪ Strong wind speed causes faster drying time	▪ Static friction (f_s) $f_s = \mu_s \, . N$ ▪ Kinetic friction (f_k) $f_k = \mu_k \, .N$ ▪ Room temperature ▪ T = 27˚C ▪ Atmospheric air pressure ▪ 760 Hg = 1 atm ▪ Ideal wind speed ▪ 19-35 km/h

4.2 Exploration Activities by the Trial Group

Exploration of physical concepts and processes by the trial group, in this case the 5th semester physics students, still experienced difficulties in the first steps. This is because the learning process is different from the usual formal learning. Only 2 out of 6 members of the trial group could identify the first steps in the exploration process. Reflective questions are asked to control for any misconceptions that arise. The reflective questions that the researcher gave in the first step had a good impact in the second step, where all members of the trial group answered correctly the second step, namely formation. 3 out of 7 members of the trial group could not describe the process of forming a pottery body scientifically. Reflective questions were asked to spur the trial group to think scientifically in describing the process of forming the pottery body. Each step of making pottery has different difficulties and is not based on the order. The exploration steps that have more high difficulty level are steps 3 and 4. There are new answers that emerge in steps three to five regarding air humidity, heat transfer, and the relationship between temperature and pressure. The trial group became accustomed to doing exploration because it was done not once but repeatedly. In the end, it can be seen that there is a development in the ability to think in exploring utilizing local wisdom from the experiences that have been passed. New answers that emerge are included in the revised exploration matrix.

The results of the exploration score achievement of the trial group are shown in table 7.

Table 7: Exploration Score of Trial Group

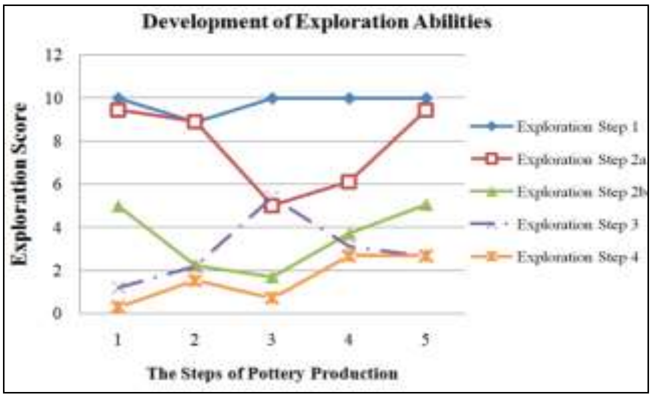
Pottery production steps	Exploration Steps				
	1	2		3	4
		a	b		
1	3.33	1.67	0.00	0.69	0.00
2	10.00	10.00	5.71	1.52	1.43
3	10.00	5.00	0.83	6.75	0.89
4	10.00	8.33	4.81	3.22	1.06
5	10.00	8.33	4.17	3.28	2.67

Exploration scores range from 1-10 based on the scoring rubric.

4.3 Exploration Activities by The Target Group

The target group also experienced difficulties in exploring concepts and physical processes at the beginning of the activity as was the case with the trial group. All members of the target group answered the first step correctly but 3 out of 9 members of the target group could not describe the process of scientifically processing the material. Reflective questions are given to spur the target group to think scientifically in describing the material processing process. Only 2 out of 9 members of the target group can describe the process of formation scientifically. The answers of other group members were more to the craftsmen's explanation and not on scientific explanations. Reflective questions are given to stimulate the target group to think scientifically in describing the formation process. Each step of making pottery has a different difficulty and is not based on the order. Exploration steps 3 and 4 are steps that have a higher difficulty level. There are new answers that appear in the next steps, namely about conductivity, combustion time, volume burn loss and mass burn loss. The repeated exploration activities make the target group accustomed to doing it. In the end, it can be seen that there is a development in the ability to think in exploring utilizing local wisdom from the experiences that have been passed. New answers that emerge are included in the revised exploration matrix.

The development of the target group's exploration ability is shown in graphic 1.



Graphic 1: Development of Exploration Abilities

There is a development and increased ability to think in exploring from the first step to the next steps. It can be seen that the exploration ability scores of steps 1 and 2 are higher than steps 3 and 4. This shows that students find it easier to formulate concept networks than to explore and formulate concepts and physical processes. This is due to the lack of experience in analyzing cases of physics comprehensively. Assignments or practice questions received in formal learning emphasize the assignment of certain formulas that are mechanistic. There was an increase in the exploration of the concept and process of drying pottery. Many students explore the microclimate because the material is not too complex. From the results of graphic analysis, it can be concluded that the ability to explore a network of concepts and comprehensive formulations utilizing local wisdom, apart from being influenced by the experience of higher order thinking learning processes, also depends on the complexity of the object or problem being discussed.

5. Discussion

Based on the research data, it can be seen that there are various concepts and physical processes in making pottery. Bello [11] found that there was an influence between understanding of local wisdom and students' understanding in learning. Utilizing local wisdom in learning makes local wisdom not only seen and interpreted through one's own perceptions, but is brought in the classroom to be explained scientifically using existing knowledge. It can also be seen that the higher order thinking learning process can be found in exploratory learning utilizing local wisdom. Medellu [12] suggest that knowledge and values in society shape individual experiences in understanding and analyzing facts and phenomena in the environment. Exploratory learning raises the potential in building learning initiatives characterized by student efforts to explore concepts and physical processes about pottery production utilizing local wisdom. Learning takes place more naturally, not just a transfer of knowledge from the teacher in the classroom. There are deviant answers which are controlled by reflective questions. Lee and Wong [13] found that reflective questions can correct mistakes found in solving problems. This also leads students to reflect on themselves in correcting mistakes and reconstructing experiences. The exploratory process carried out by the research team, the trial group and the target group showed the development of the ability to think based on experience. There are many physical concepts and processes that can be explored because matter is flexible, not limited to certain materials.

6. Conclusion

HOTL-DI type B explorative learning model has the potential to improve students' higher-order thinking skills in exploring physical processes and concepts in the environment utilizing local wisdom. This more natural exploratory learning provides a new learning atmosphere so that it shows a positive response from students in the form of motivation, interest, and learning initiatives. Assistance is still needed because students still have difficulty exploring at the beginning of the activity. The ability to think in exploring physical processes and concepts continues to increase to the next meeting. By getting used to exploring, students are able to identify phenomena, describe them based on local wisdom and facts, understand scientific concepts and processes, and formulate comprehensive concept networks.

7. Acknowledgment

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